

ME 2141

Hibbeler, *Mastering Engineering with Engineering Mechanics: Statics (15e)*, Pearson

Sections 1.1-1.6 and 2.1-2.6

Learning goals

- a. Define mechanics
- b. Understand and work with the two unit systems
- c. Apply a prefix to a number
- d. Round a final answer appropriately



What is mechanics?

Study of what happens to a “thing” (the technical name is “**body**”) when force are applied to it.



Units of measurement

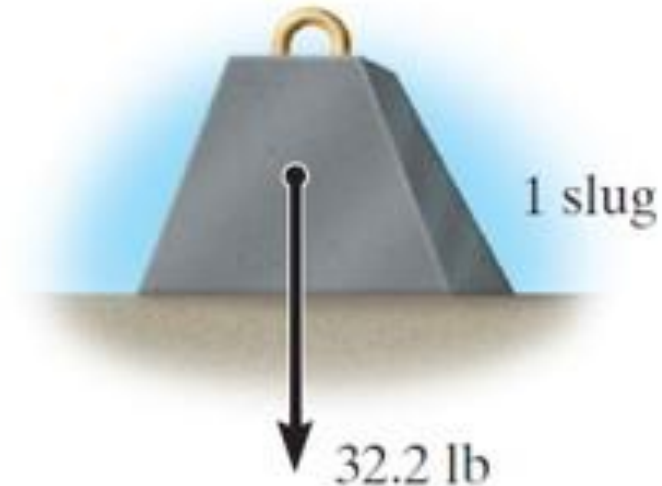
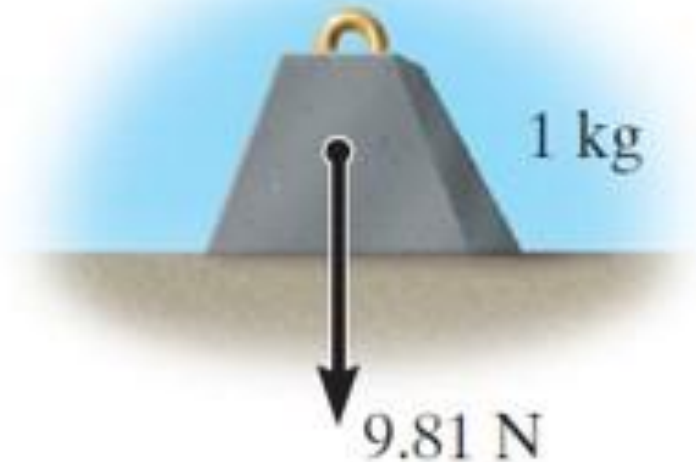
Four fundamental physical quantities

1. Length
2. Time
3. Mass
4. Force

Unit systems

We will work with **two** unit systems in statics:

- International System (SI)
- U.S. Customary (USCS)
system



Summary of unit systems

Name	Length	Time	Mass	Force
S.I.	<u>meter</u>	<u>second</u>	<u>kilogram</u>	<u>Newton</u>
U.S.C.S.	<u>Foot</u>	<u>second</u>	<u>slug</u>	<u>lbs</u>

Work problems in the units given (S.I. or U.S.C.S.) unless otherwise instructed!

Important prefixes

- Giga
 - G: 10^9
- Mega
 - M: 10^6
- Kilo
 - K: 10^3
- Milli
 - m: 10^{-3}
- Micro
 - μ : 10^{-6}
- Nano
 - n: 10^{-9}

Example:

55.4 kN is how many Newtons?
55,400 N

Numerical calculations

- Use an appropriate number of **significant figures**
 - At least 3 for **final answer**
 - As many as you can for **intermediate calculations**
- Be consistent when **rounding**
 - greater than or equal to 5, round up

$$(3528 \Rightarrow 3530$$

- smaller than 5, round down

$$(0.03521 \Rightarrow 3.52 \cdot 10^{-2}$$

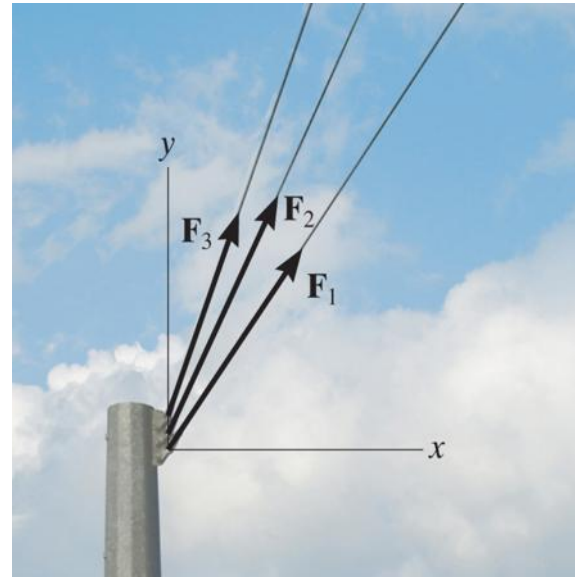
Class question

For a problem, your calculations show the final answer as 12345.6 N. What should you write as your final answer?

- A. 12345.6 N
- B. 12.3456 kN
- C. 12 kN
- D. 12.3 kN
- E. 123 kN

Learning goals

- a. Define scalar and vector
- b. Perform basic vector operations: multiply a vector by a scalar
- c. Resolve a 2-D vector into components.
- d. Calculate the magnitude and angle of a 2-D vector given its components
- e. Add 2-D vectors by adding components

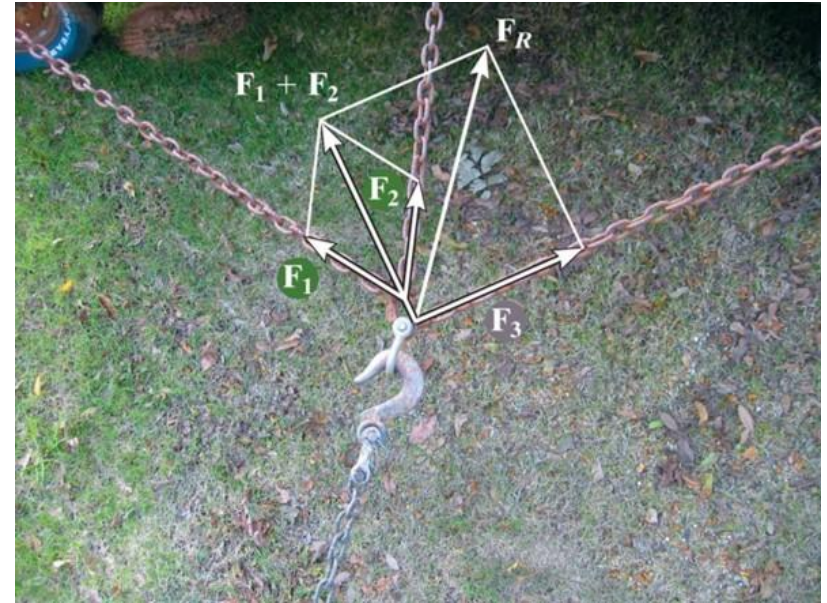


Application

There are three forces acting on the hook due to the chains.

We need to decide if the hook will fail (bend or break).

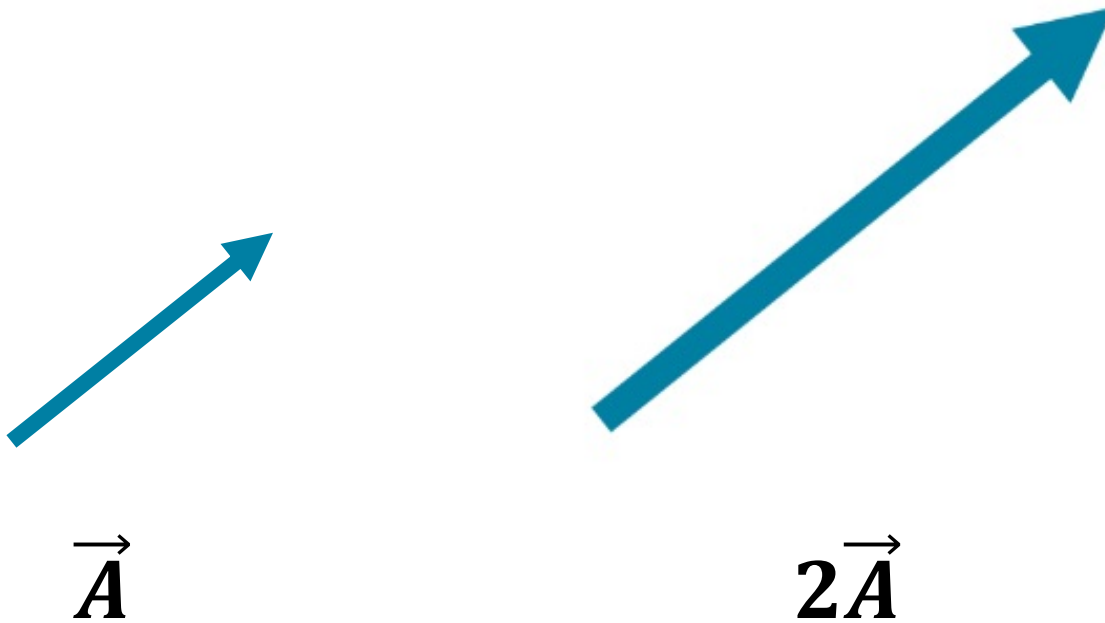
To do this, we need to know the resultant or total force acting on the hook from the three chains.



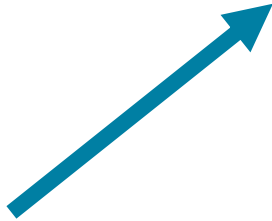
Scalars and vectors

	Scalars	Vectors
Examples:	<u>mass speed volume time</u>	<u>Force velocity</u>
Characteristics:	“How <u>much</u> ?”	“How <u>much</u> ?” + “In what <u>direction</u> ?”
Notation:	None	<u>bold</u> font or $\vec{v}$

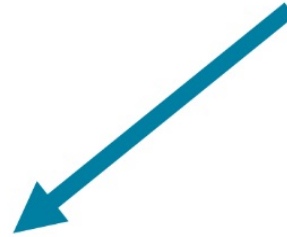
Vector operations



Vector operations

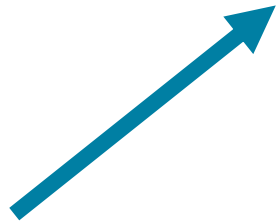


$\vec{A}$



$-\vec{A}$

Vector operations



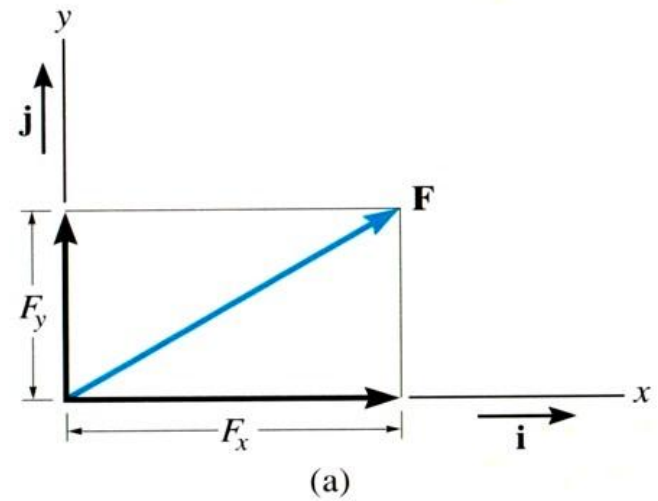
$\vec{A}$



$0.5\vec{A}$

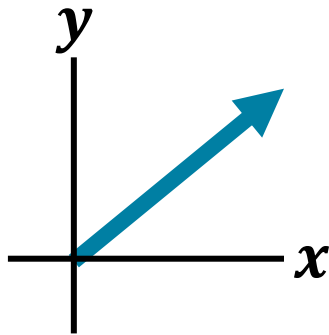
Vector components

- We **resolve** a vector into x and y components using trig
- We use the “unit **vectors**” $\mathbf{i}$ and $\mathbf{j}$ to designate the x and y-axes.
- Each component can be positive or negative.

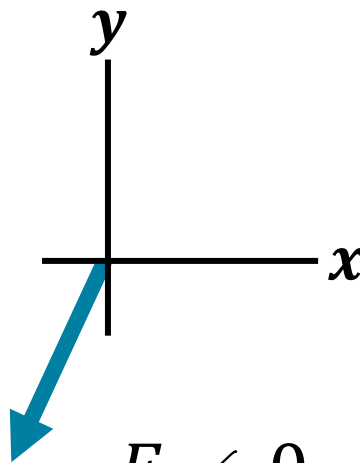


Example

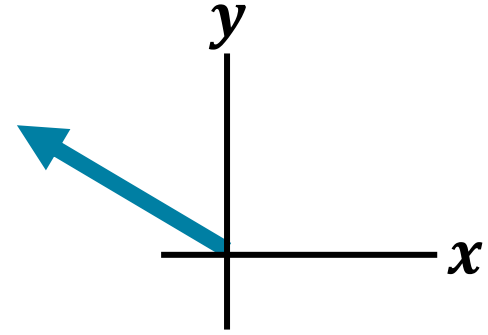
$$\mathbf{F} = F_x \mathbf{i} + F_y \mathbf{j}$$



$$F_x \underline{\hspace{0.5cm}} 0$$
$$F_y \underline{\hspace{0.5cm}} 0$$



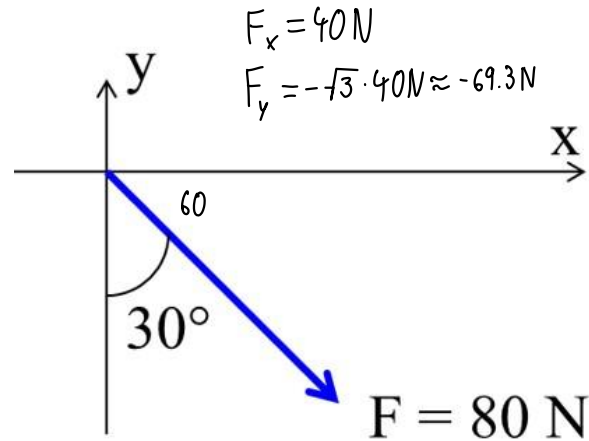
$$F_x \underline{\hspace{0.5cm}} 0$$
$$F_y \underline{\hspace{0.5cm}} 0$$



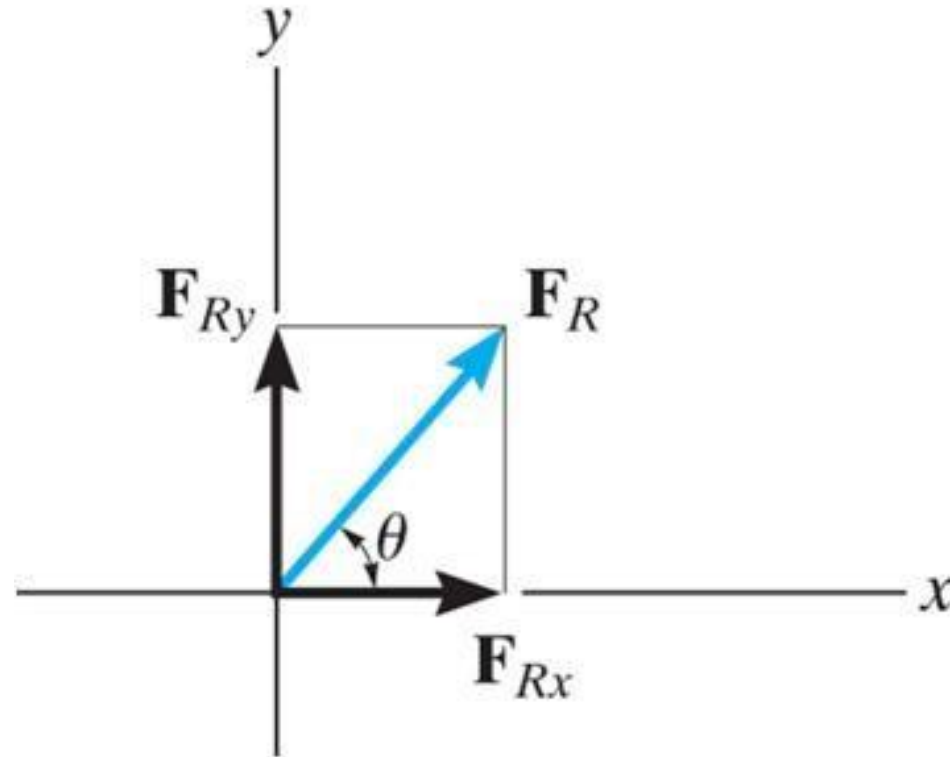
$$F_x \underline{\hspace{0.5cm}} 0$$
$$F_y \underline{\hspace{0.5cm}} 0$$

Example

Calculate the x and y components of vector **F**



Finding magnitude and angle for a vector



$$\theta =$$

$$F_R =$$

Addition of vectors: 3 steps!

1. Resolve each vector into x and y **components**.
2. Add all the x-components together. Add all the y-components together. These two totals are the x and y-components of the resultant **vector**.
3. Find the magnitude and angle of the resultant **vector**.

Example

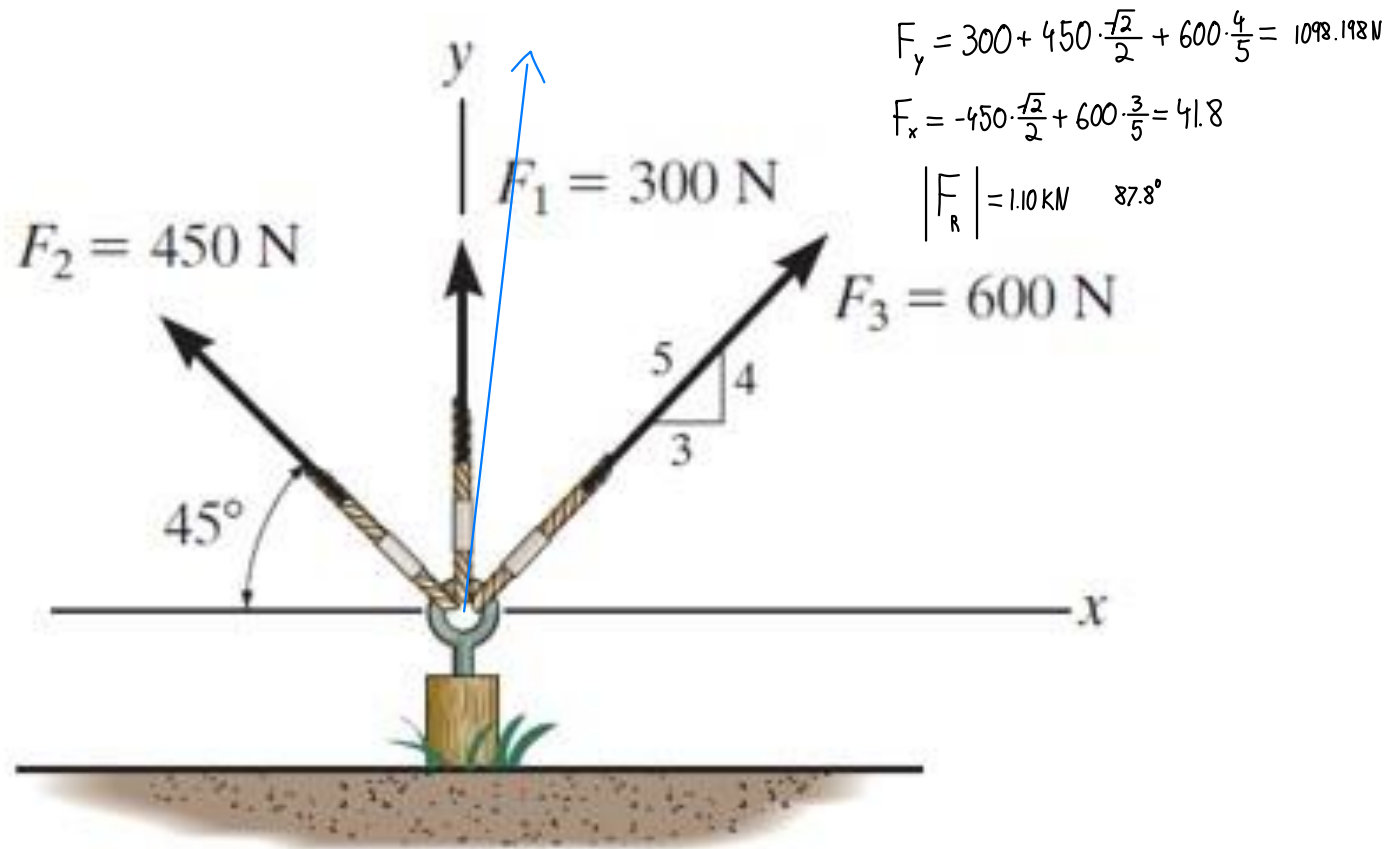
Determine the magnitude of the resultant ($F_1 + F_2$) force in N when $F_1 = \{10i + 20j\}$ N and $F_2 = \{20i + 20j\}$ N.

$$F_R = 30i + 40j$$

$$|F_R| = 50\text{ N}$$

Example

Three concurrent forces acting on a tent post. Find the magnitude and angle of the resultant force.



Learning goals

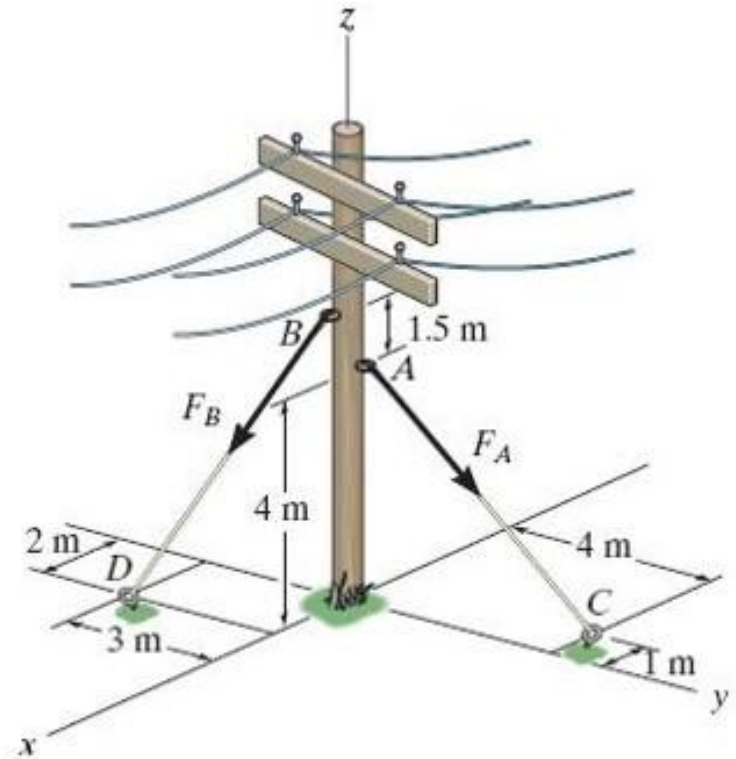
- a. Calculate the components of a 3-D vector.
- b. Define unit vector.
- c. Form a unit vector out of a 3-D vector
- d. Add 3-D vectors



Application

Many structures and machines involve 3-D space.

For example, the power pole has guy wires in various directions to help keep it upright in high winds.

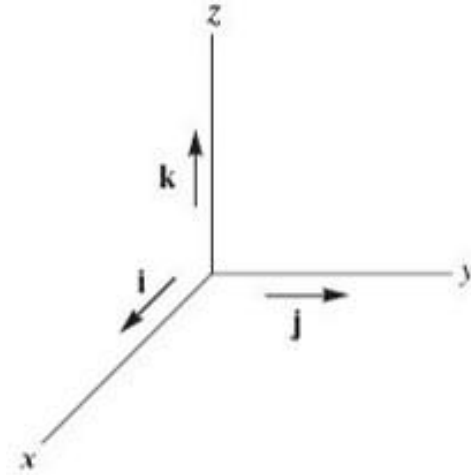


How do we analyze 3-D vectors?

Unit vectors

For a vector $\mathbf{A}$, with a magnitude of A , a unit vector is defined as

$$\mathbf{u}_A = \frac{\mathbf{A}}{A}.$$



Three characteristics of a unit vector :

1. Its magnitude is 1.
2. It is dimensionless (has no units).
3. It points in the same direction as the original vector ($\mathbf{A}$).

The unit vectors $\mathbf{i}$, $\mathbf{j}$, and $\mathbf{k}$ are along the _____ x, y, and z axes.

Finding 3-D unit vectors

The formula for finding the unit vector of **any** 3-D vector:

$$\mathbf{u}_A = \frac{\mathbf{A}}{A} = \frac{A_x}{A}\mathbf{i} + \frac{A_y}{A}\mathbf{j} + \frac{A_z}{A}\mathbf{k}$$

Example: If $\vec{A} = 4\mathbf{i} + 3\mathbf{j} - 2\mathbf{k}$, find u_A

$$|\vec{A}| = \sqrt{4^2 + 3^2 + 2^2} = \sqrt{29}$$

$$\vec{u}_A = \frac{1}{\sqrt{29}}\vec{A}$$

Addition of 3-D vectors

To add 3-D vectors, first resolve them into their x, y, and z components. Then, add the x, y, and z components.

$$\mathbf{F}_R = \Sigma \mathbf{F} = \Sigma F_x \mathbf{i} + \Sigma F_y \mathbf{j} + \Sigma F_z \mathbf{k}$$

For example, if

$$\mathbf{A} = A_x \mathbf{i} + A_y \mathbf{j} + A_z \mathbf{k} \text{ and}$$

$$\mathbf{B} = B_x \mathbf{i} + B_y \mathbf{j} + B_z \mathbf{k}, \text{ then}$$

$$\mathbf{A} + \mathbf{B} = (A_x + B_x) \mathbf{i} + (A_y + B_y) \mathbf{j} + (A_z + B_z) \mathbf{k}$$

Example

If $F = \{10i + 10j + 10k\} \mathbb{N}$ and

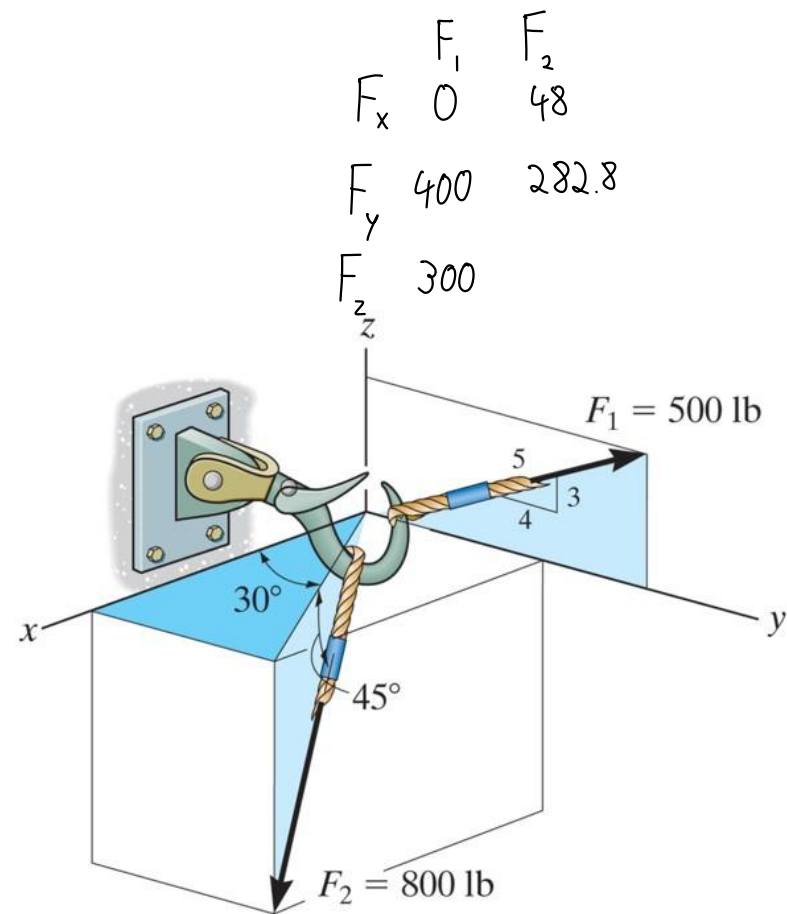
$G = \{20i + 20j + 20k\} \mathbb{N}$, then $F + G = \{30(i+j+k)\} \mathbb{N}$

Example

Given: Two forces F_1 and F_2 are applied to a hook.

Find: The resultant force in Cartesian vector form.

$$F_R =$$



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Suck My balls